

Study of EUV Pinch Dynamics and Overcoming Collector and Mask Issues

D. N. Ruzic*, H. Shin, V. Surla, J. Sporre, W. M. Lytle, R. E. Lofgren, M. J. Neumann

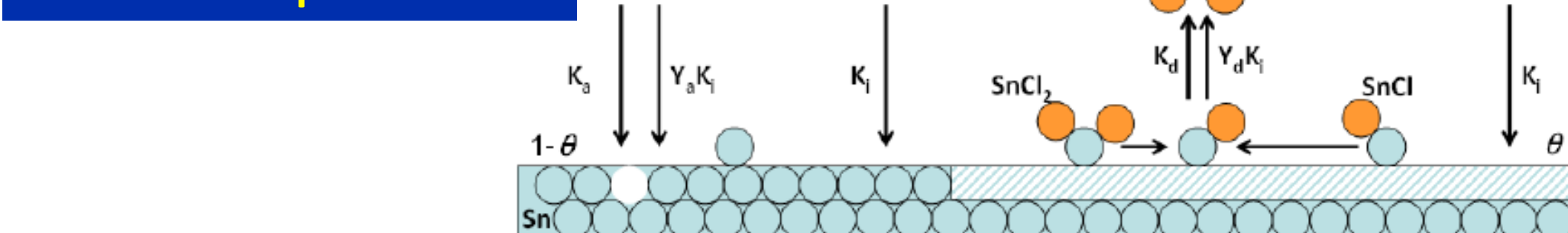
Center for Plasma-Material Interactions, Department of Nuclear Plasma and Radiological Engineering, University of Illinois at Urbana-Champaign, Urbana, IL 61801 USA
*contact email: druzic@illinois.edu

Abstract

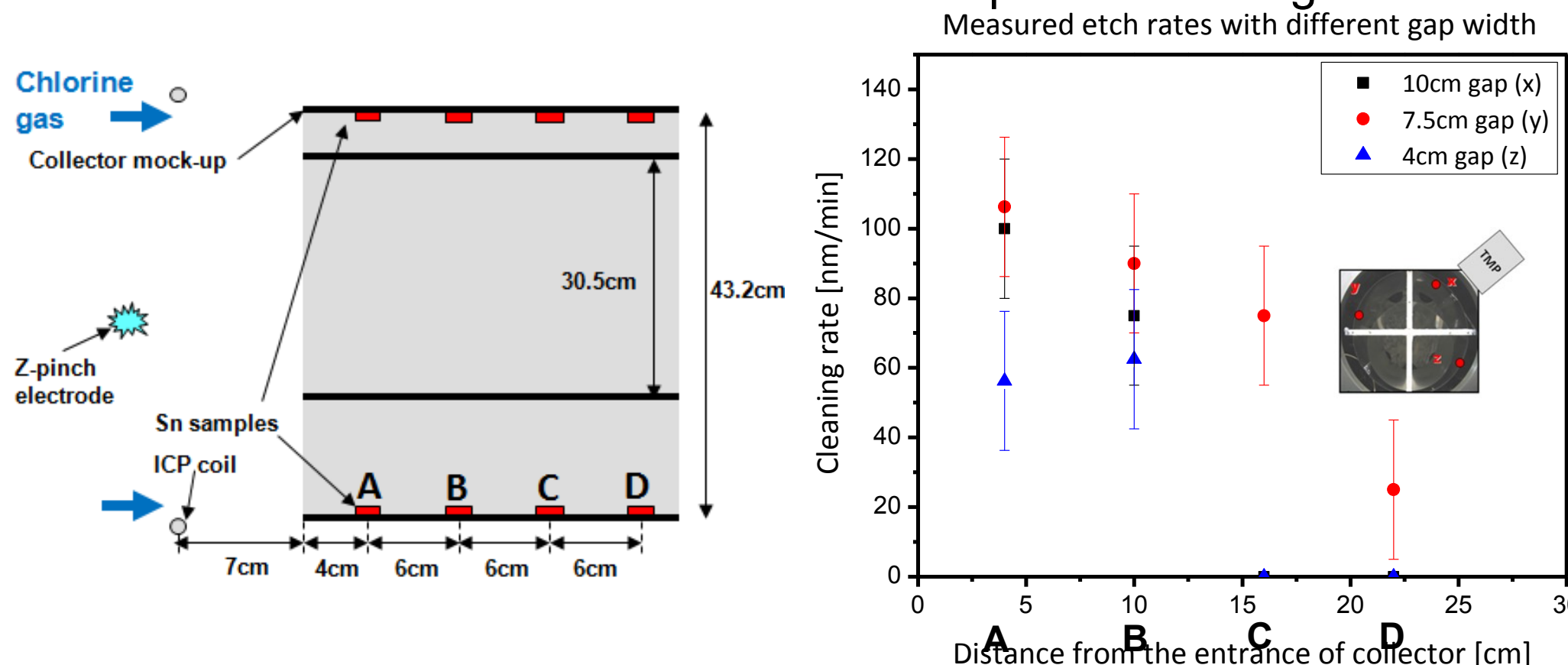
The Center for Plasma Material Interactions (CPMI) at the University of Illinois at Urbana Champaign continues to work on key areas related to extreme ultraviolet light (EUV) lithography, specifically in diagnostic development for better understanding of the source types, cleaning of the optics, and particle removal for masks and wafers. CPMI is currently equipped with various EUV sources: discharge produced plasmas (DPP), laser produced plasmas (LPP), as well as laser assisted DPP (LADPP) and the diagnostics in house will allow for the investigation of the dynamics of these sources and the available debris mitigation methods. The debris resulting from these sources will be cleaned from our existing plasma based cleaning techniques- the ICP and the remote plasma system. Moreover, plasma transport and surface reaction between Sn and chlorine plasma are investigated to help design a cleaning system in Sn fuel EUV source. In yet another key area of EUV research, CPMI has developed a nanoparticle-cleaning system for masks and wafers called PACMAN (plasma-assisted cleaning by metastable atom neutralization) and the results obtained therein are also presented.

Plasma based Sn debris cleaning methods

Reactive ion etching of Sn with chlorine plasma



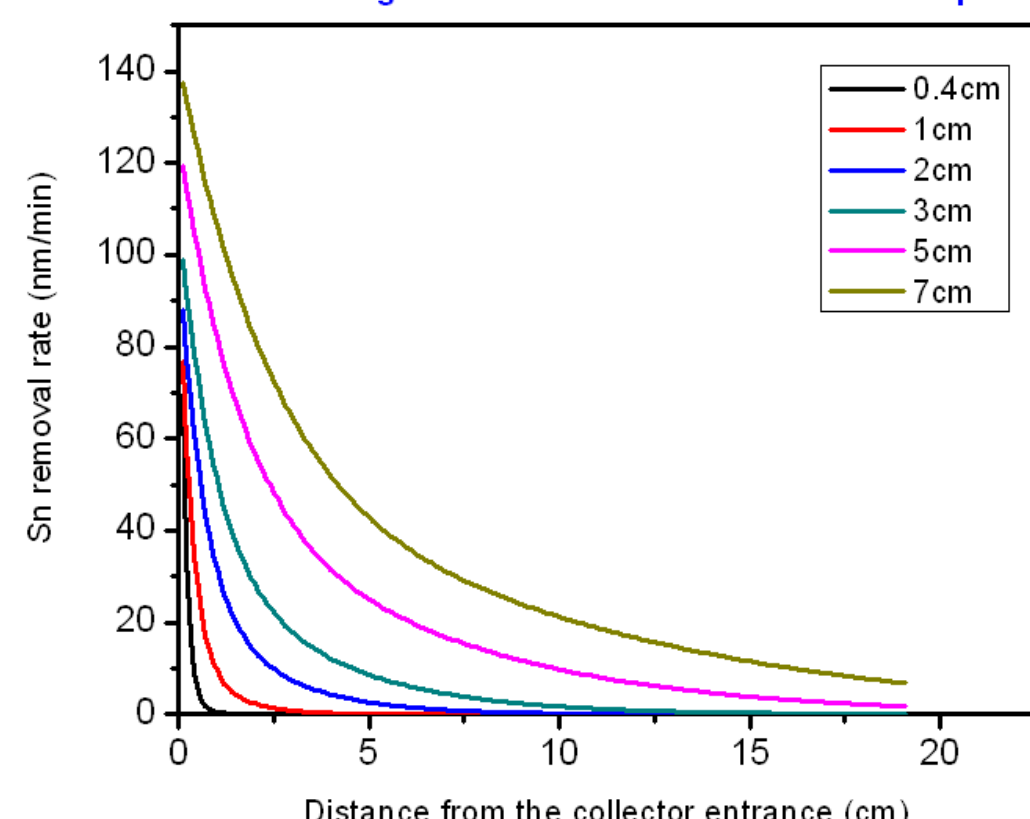
- CPMI has been investigating a method to selectively remove Sn debris from Ru mirror surface with chlorine plasma etching.



- Plasma transport through different gap, chlorine radical uniformity, and pumping flow effects on the cleaning are investigated.

- Simple analytical model validated by experiments will help design a fast and *in situ* cleaning technique in EUV source systems.

Predicted cleaning rates in the EUV collector with multiple shells

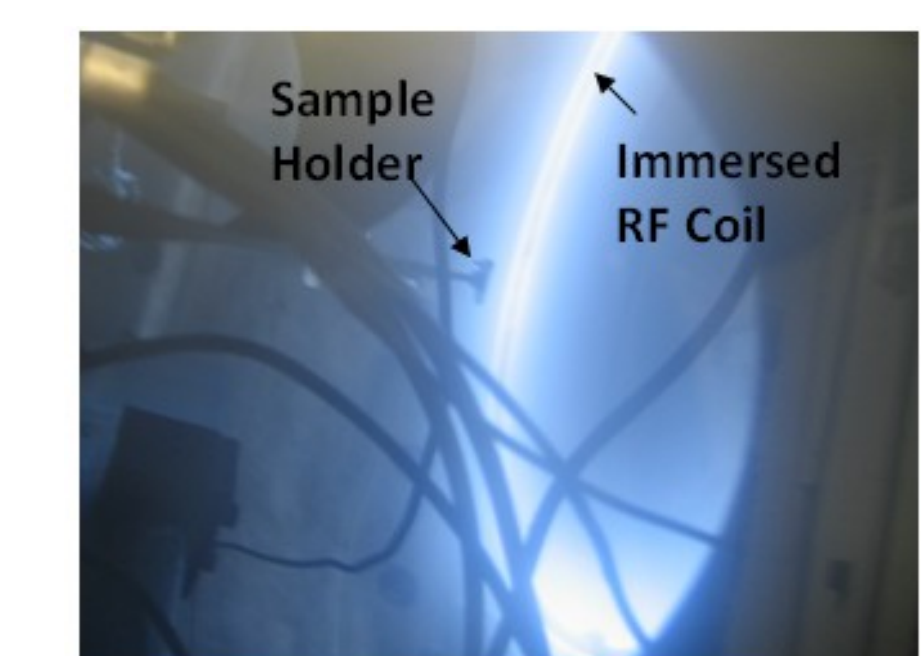


- Understanding plasma transport in shells and surface reaction leads to the development of cleaning rate prediction model.

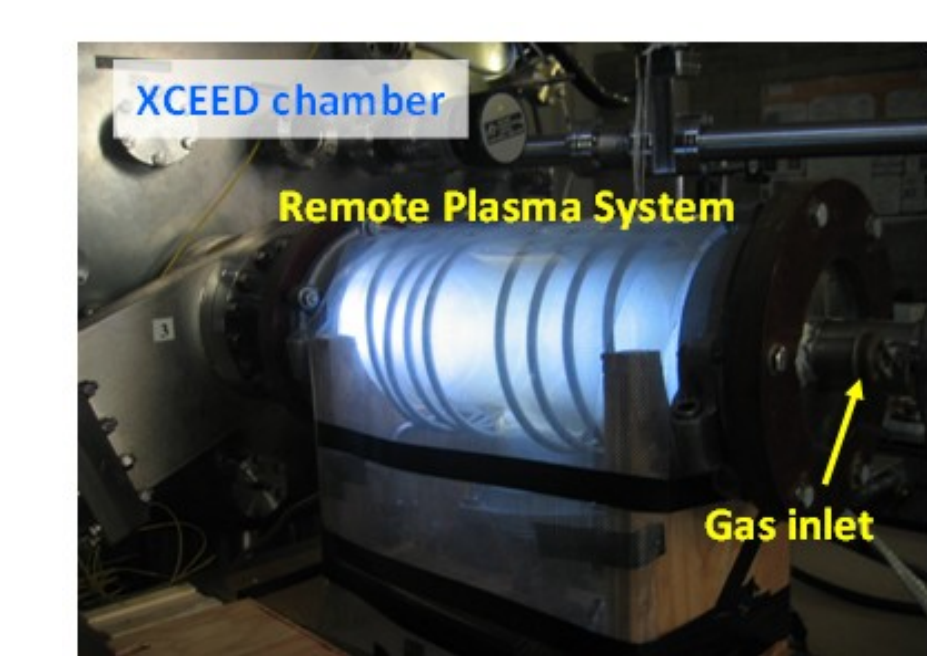
- Non-uniform cleaning rate could be in favor of Sn debris contamination, which is also non-uniform.

Efficacy of cleaning Sn contaminant in CPMI LADPP by remote plasma and inductively coupled plasma

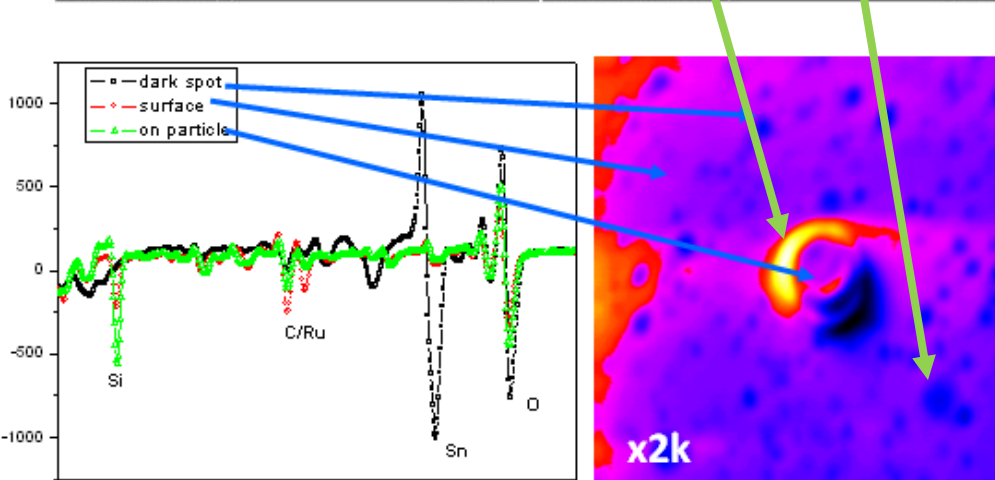
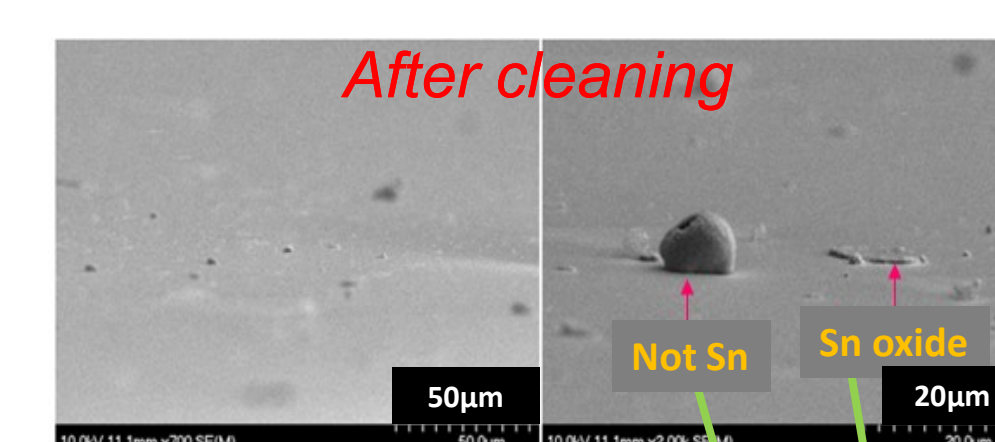
- Surface is contaminated by Sn micro-particles by laser ablation and cleaned by two different method but with the same time and pressure.



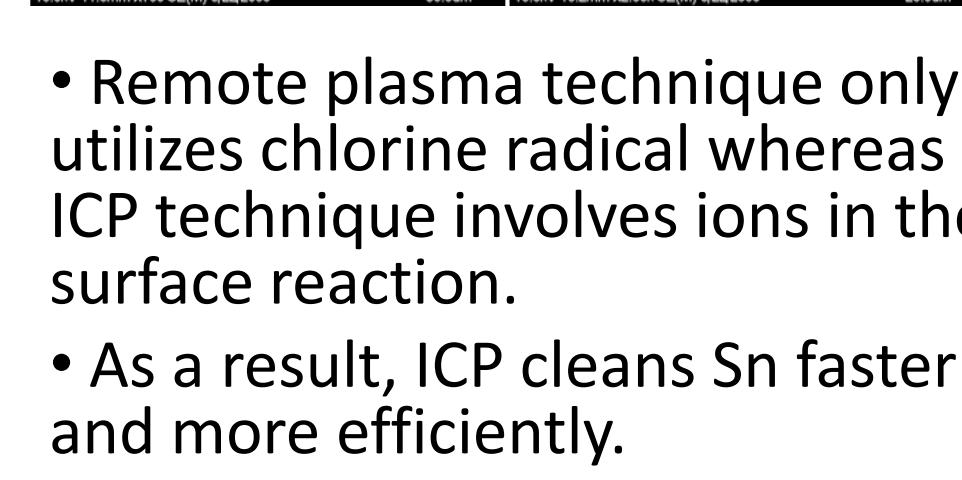
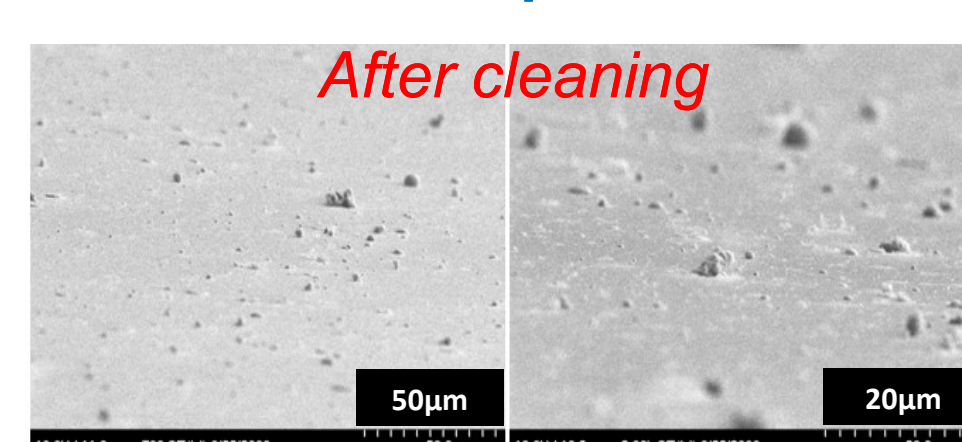
Inductively coupled plasma



Remote plasma



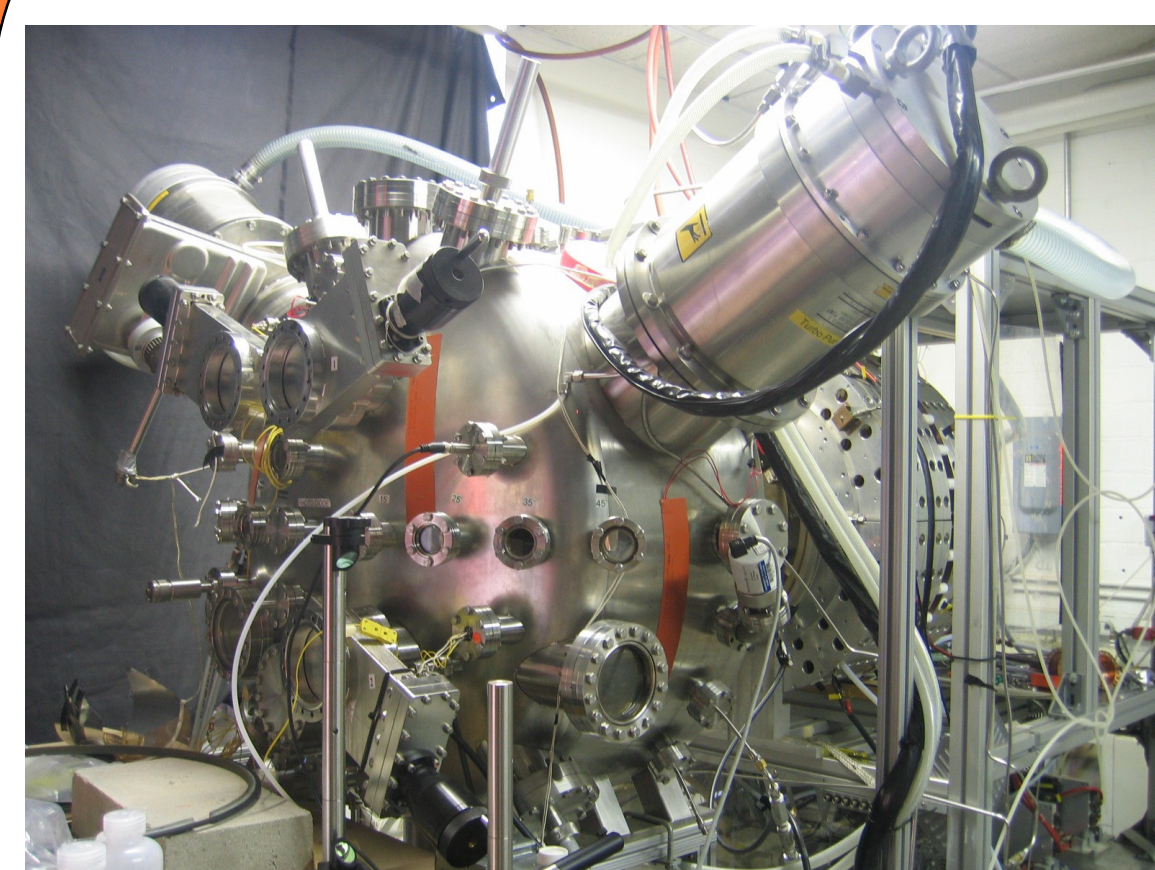
AES scan to show the remaining large particles after ICP cleaning is not Sn.



Remote plasma technique only utilizes chlorine radical whereas ICP technique involves ions in the surface reaction.

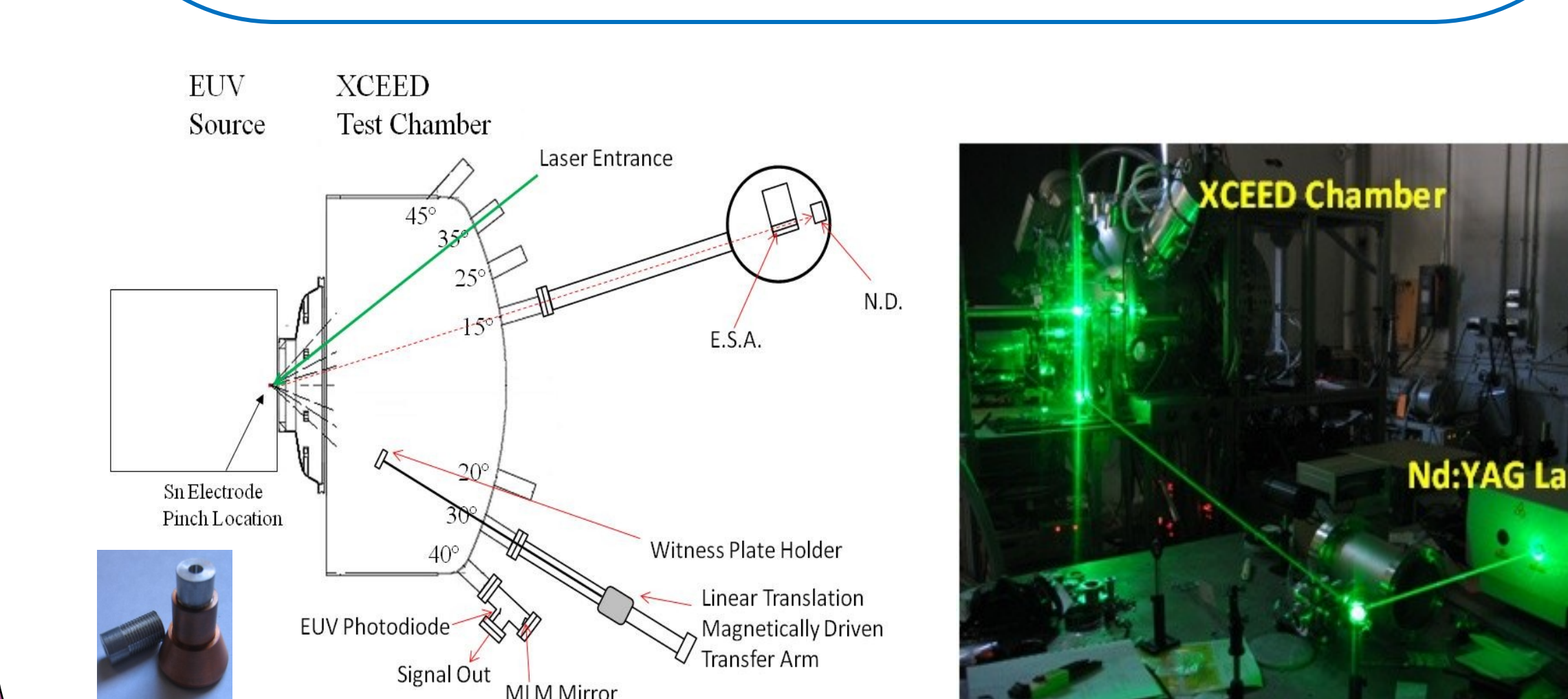
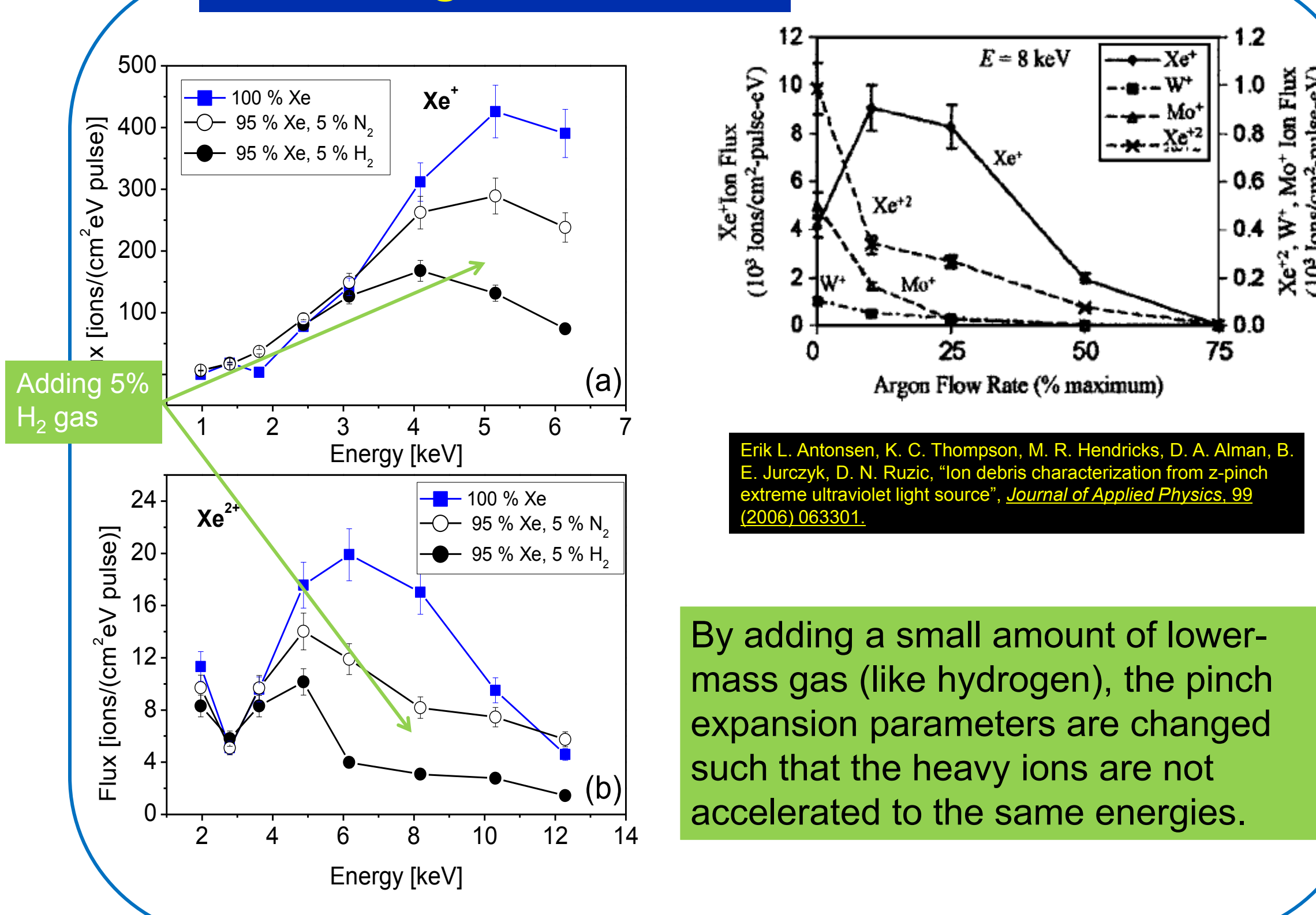
- As a result, ICP cleans Sn faster and more efficiently.
- In a cleaner environment, the plasma based cleaning technique will work better.

Investigation of the dynamics of the sources and the available debris mitigation methods



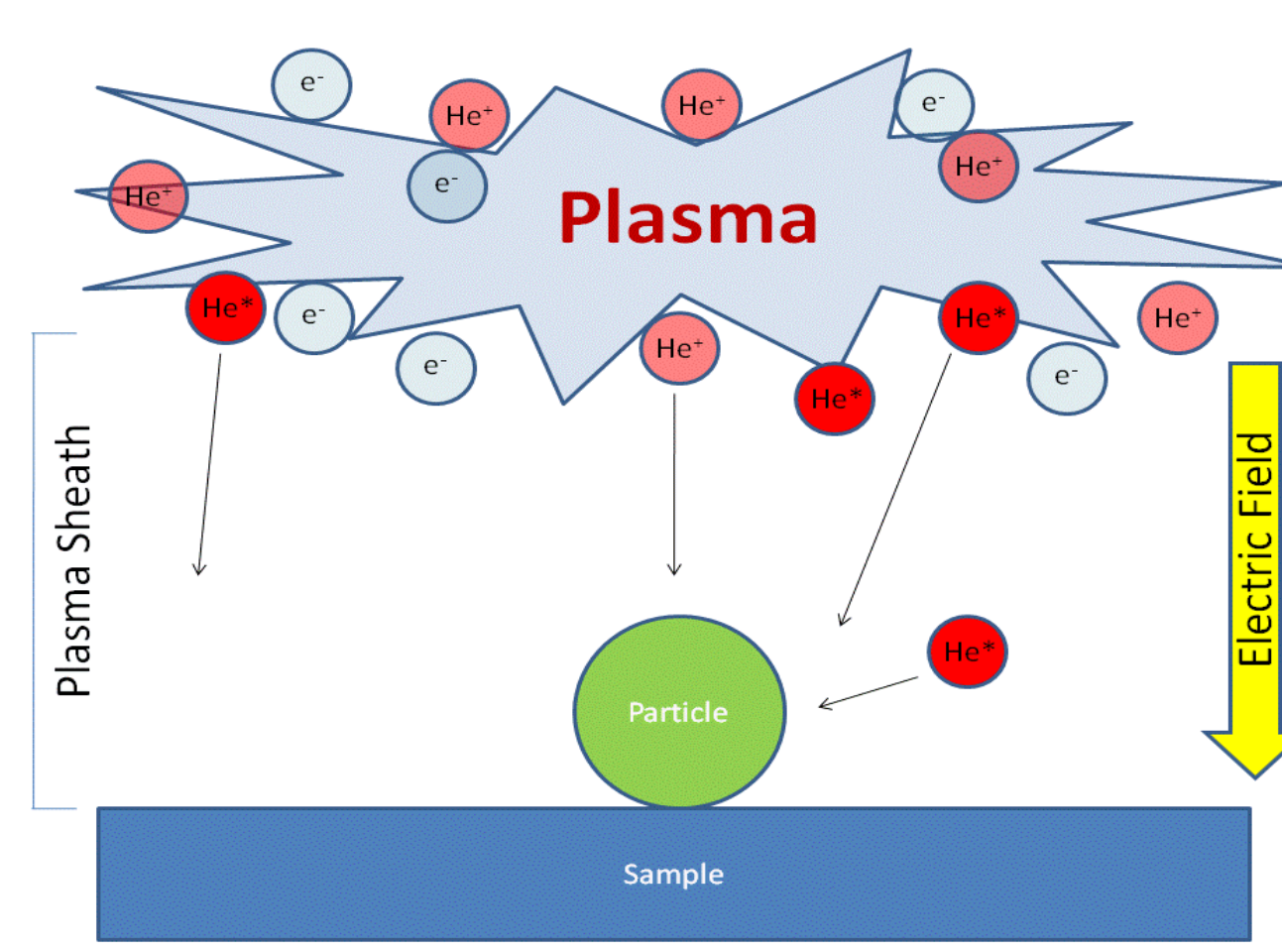
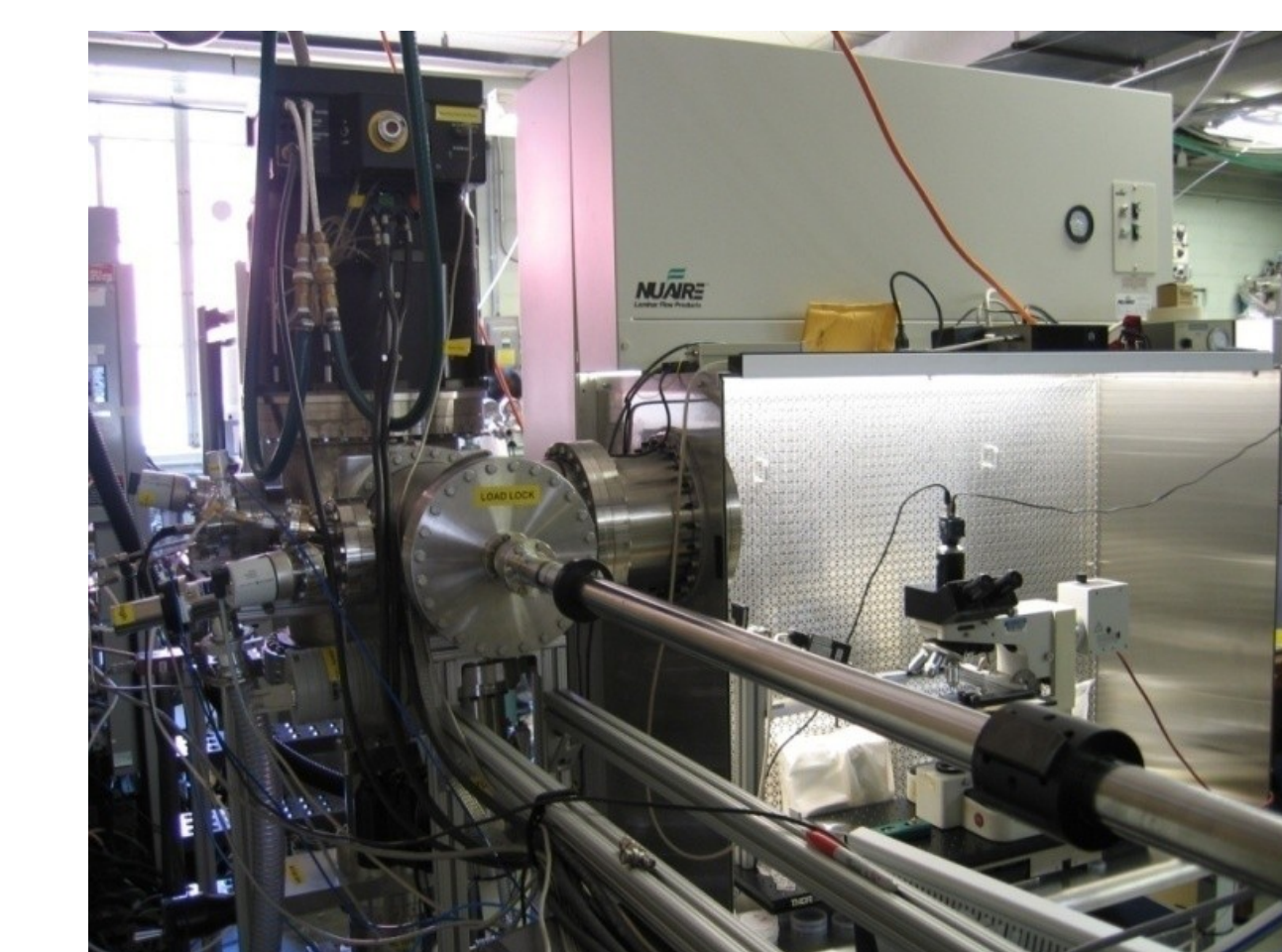
XTS 13-35 DPP EUV source system (named as XCEED) at CPMI

Debris mitigation methods



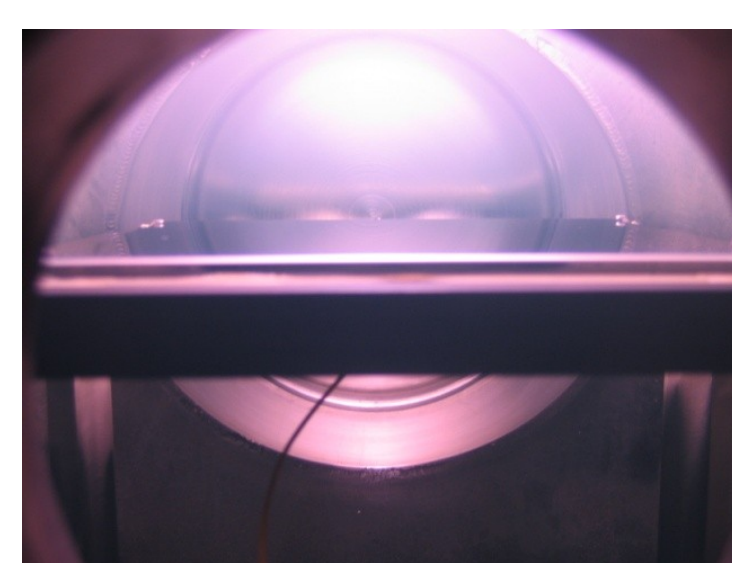
- CPMI also investigate LADPP-like debris by ablating solid Sn electrode with an Nd:YAG laser during the pinch operation.

Plasma-assisted cleaning by metastable atom neutralization (PACMAN)

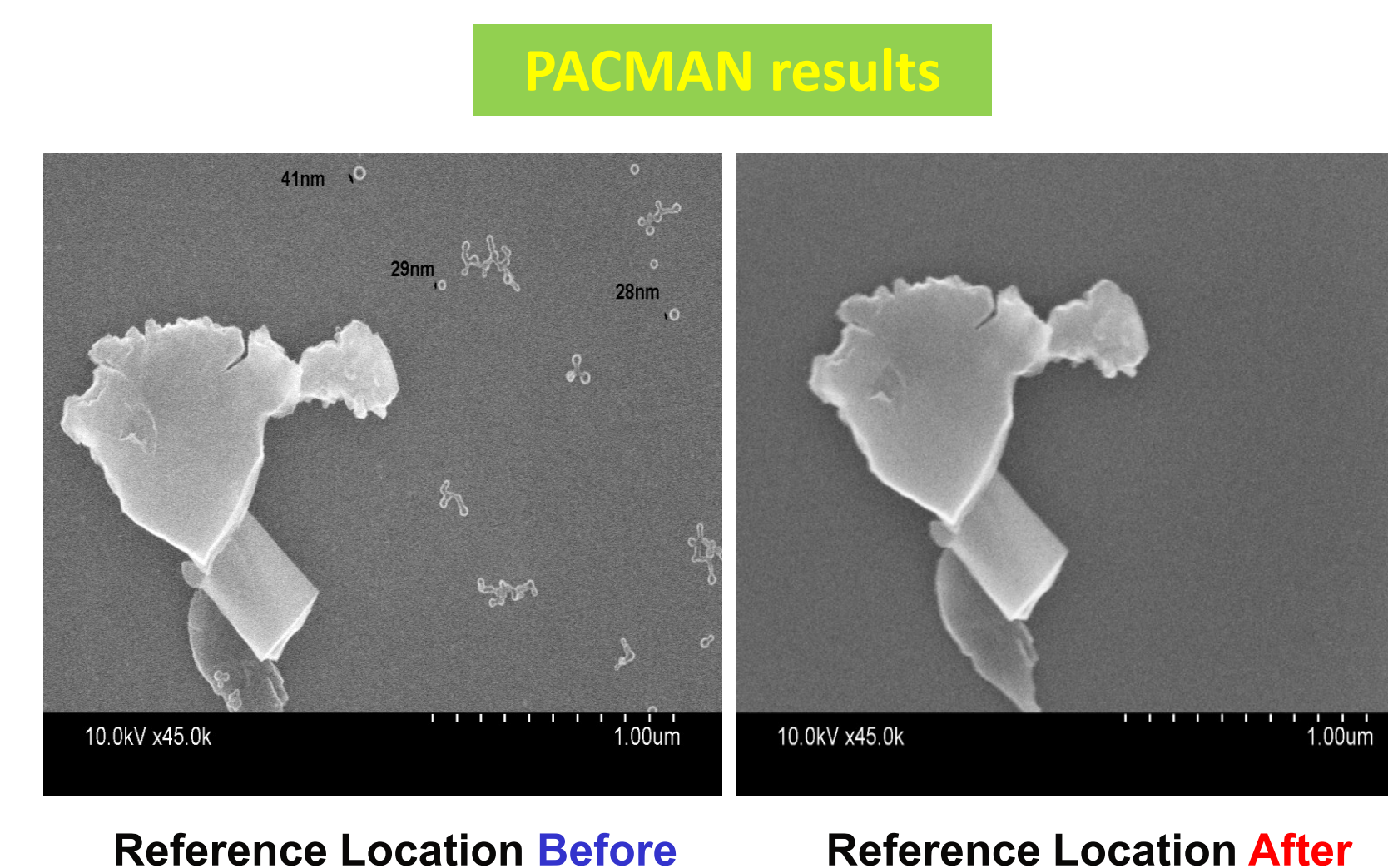


< Proposed PACMAN theory >

- Plasma creates electrons, helium ions, and helium metastables
- He ions directed to the surface by plasma sheath electric field
- Metastables (non ionized) diffuse to the surface/particle
- He ions and metastables impart energy to atoms of the particle
- Particle bonds break
- Volatilization of particle occurs
- Particle is removed similar to etching



- Particle contamination on mask or wafer is a critical issue in shrinking the pattern size on the chip.
- CPMI developed a plasma-assisted cleaning method and showed a success in removing nano-particles.



Reference Location Before Reference Location After

- For more detail, please visit our other poster:

W. M. Lytle et al, "Plasma Cleaning of Carbon and Nanoparticles from EUV Materials"

Conclusion

- The Center for Plasma Material Interactions (CPMI) at the University of Illinois at Urbana Champaign continues to work on developing diagnostics to understand EUV source dynamics and debris generation better.

- Knowing the origin of the debris enables us to develop various plasma based cleaning techniques.

- Beyond the EUV source and collector optics, we are investigating a cleaning method for particle or carbon contamination on the mask or wafers.

Acknowledgements

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- Sample analysis was also carried out at the Micro and Nanotechnology Laboratory at the University of Illinois Urbana Champaign.

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